SELECTING THE RIGHT RF SWITCH

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After the system design has been blocked out, after the individual component specifications to achieve the overall system's performance have been identified, the crucial moment arrives...actual components selection! Amplifiers, filters, mixers and the like, generally receive proper deliberation during the component selection stage of RF systems design. However, the effect of switch parameters on the overall system's performance is often overlooked. In order to select the 'right' switch, knowledge of switch parameters and their interrelation is necessary. Along with VSWR, insertion loss, isolation and DC power consumption, there are other notable switch characteristics such as switching speed, transition time, intercept points, and compression points that require proper attention in order to meet the overall system specifications. Understanding of the advantages and disadvantages of basic switch technologies is also invaluable in selecting the right RF switch. In the following paragraphs some of the more subtle switch parameters will be discussed and four basic switch technologies (relays, GaAs MMIC's, PIN & Schottky diodes) will be compared. For the sake of simplicity, SP2T switches have been used throughout the text for comparisons since these are representative of multi-throw switches in general.

SWITCH PARAMETERS:

Transition Time:

Transition time is the time required for the RF voltage envelope to go from 10% to 90% for on-time, or 90% to 10% for off-time. At the 90% point, the signal is within 1 dB of its final value. Measuring the 100% signal level is difficult to accomplish because the RF envelope approaches its final value asymptotically (see Figure 1). Another factor that makes the 100% point difficult to measure is the asymmetry of the waveform caused by the superposition of switching transients on the envelope (see Figure 2B).

Switching Speed:

Switching speed is the time required for the switch to respond at the output when the control line input changes. Switching speed includes the driver propagation delay as well as transition time and is measured from the 50% point on the control voltage to the 90% (for the on-time) or 10% (for the off-time) of the RF voltage envelope. Therefore by definition, switching speed will always be longer than transition time. This difference is dramatically illustrated by a GaAs FET MMIC switch where the transition time is on the order of 5 nanoseconds, but the driver propagation delay is typically 15 nanoseconds. This results in a switching speed of roughly 20 nanoseconds, where 5 nanoseconds may have been expected had the designer considered only the transition time. Figure 1 also shows the transition time and switching speed for a typical SP2T GaAs MMIC switch with an internal TTL compatible driver (P/N DS0602). Note, that as discussed, the transition time is on the order of 5 nanoseconds and the total switching speed is approximately 17 nanoseconds.

Switching Transients:

Switching transients, also called video leakage or video feed through, are exponentially decaying voltage spikes at the input and/or output of an RF switch that result when the control changes. Switching transients in PIN diode switches are a result of the stored charge in the intrinsic region being quickly discharged by the control network. In balanced Schottky designs, the charge stored by the diode is very small and the majority of the transients are caused by imbalance (mismatching) within the bridge or driver circuit. GaAs FET MMIC switches have a very different switching transient mechanism. Transients in MMIC GaAs FET MMIC switches result when the rapidly changing gate voltage is coupled to the switch output through the gate to

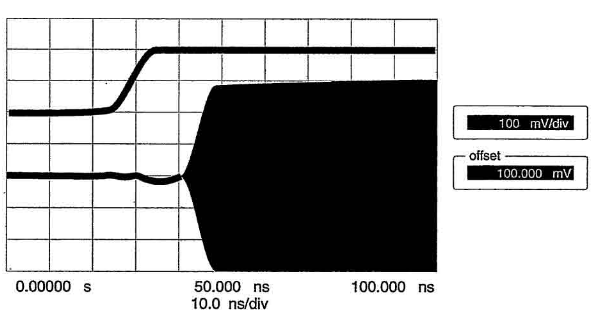


FIGURE 1 GaAs FET MMIC SWITCHING ENVELOPE

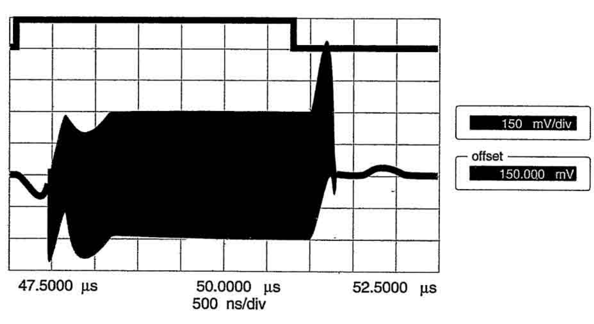


FIGURE 2B PIN DIODE SWITCH TRANSIENTS AND SWITCHING ENVELOPE

voltage is coupled to the switch output through the gate to channel capacitance of the FET. Therefore the faster the switching speed, the greater the feedthru becomes.[1]

When observed on an oscilloscope, transients are measured as the peak deviation from a steady state baseline reference. The peak value is defined as the largest positive or negative excursion from that baseline. Figure 2A shows, for a SP2T PIN diode switch with its input terminated, a peak transient value of 320 mV (positive going, on trailing edge).

There are essentially three different methods for specifying transients (video leakage): peak voltage broadband, peak voltage in-band, and power in the frequency domain (dBm). The broadband specification is a straight forward measurement of the peak voltage waveform with no filtering. The in-band specification is similar to the broadband except that a high pass or band pass filter has been added to reject out-of-band transients. This specification can be misleading since it can make the switch transients appear to be artificially low and mask the actual transient performance.

For example, consider a typical SP2T PIN diode switch (P/N DS0052) with broadband transients of 320 mV (see Figure 2A). When a 20 MHz high pass filter is added, the transients drop to 80 mV (see Figure 3A). Both are valid specifications and measurements, however, the in-band specification does mask the actual peak value of the transients and may lead to system problems if the system is sensitive to extraneous signals and does not have adequate filtering. Figure 2B shows the switching transients superimposed on the RF envelope. Note that in Figure 3B the high pass filter removed switching transients sufficiently to present an accurate representation of the actual RF envelope.

In many applications, the peak voltage of the transient waveform is not as important as the energy distribution of the transient in the frequency domain, particularly those spectral elements falling within the band of interest. Therefore, specifying transients in the frequency domain as a maximum power level (dBm) in a specified bandwidth is sometimes useful to the system designer. Frequency domain transients are a function of the repetition rate of the control signal and the measurement bandwidth. When specifying transients in the frequency domain one should specify the control conditions as well as the band of interest and the resolution bandwidth.

Figure 4 shows spectral content of the same PIN diode switch (DS0052) used in the previous time domain example. In this example, the control was switched at a 50 kHz rate (10µsec on, 10 µsec off) and the transients on the output were measured on a spectrum analyzer with the input terminated. Note that the peak power is at 5 MHz (-47 dBm) and that above 20 MHz the transients have dropped from -47 dBm to -63 dBm. Figure 5 is the same switch with a 20 MHz high pass filter added under otherwise identical test conditions. As with the time domain example (in Figure 3A & B), the transients are dramatically reduced since most of their energy is below 20 MHz.

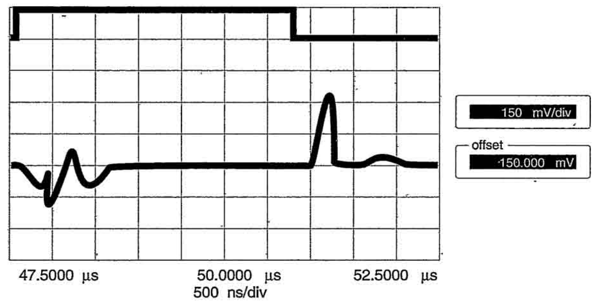


FIGURE 2A PIN DIODE SWITCH TRANSIENTS

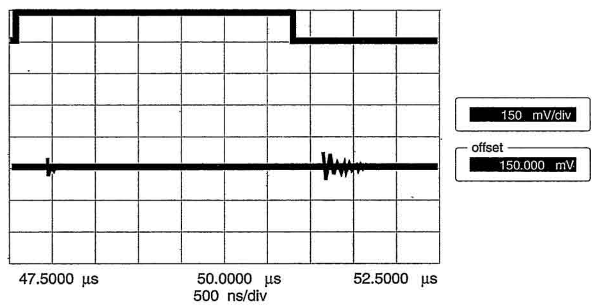


FIGURE 3A PIN DIODE SWITCH TRANSIENTS THRU A HIGH PASS FILTER

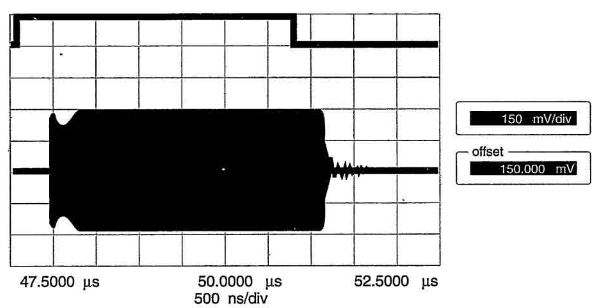


FIGURE 3B PIN DIODE SWITCH TRANSIENTS AND SWITCHING ENVELOPE THRU A HIGH PASS FILTER

Figure 6 shows the transient performance of a GaAs FET MMIC switch (P/N DS0602). The transient performance of the MMIC switch is 25 dB better than that of the PIN diode switch shown in Figure 4.

[1]Using MMIC's as Control Devices, Raymond Pengelly, Microwave Systems News, April 1989

RF Power Handling:
RF power handling is a measure of how much and, in some respects, how well a switch passes the RF signal. To quantify RF power handling, the 1.0 dB compression point is commonly specified (a specification adopted from the amplifier industry). The compression point is a measure of the deviation from linearity of the output power with respect to the input power.

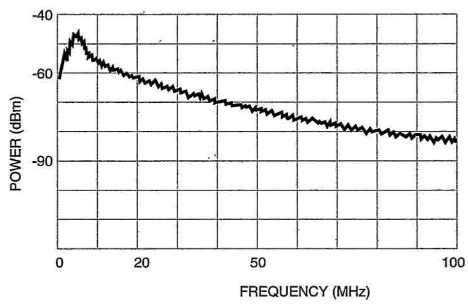


FIGURE 4 PIN DIODE SWITCH TRANSIENTS IN THE FREQUENCY DOMAIN

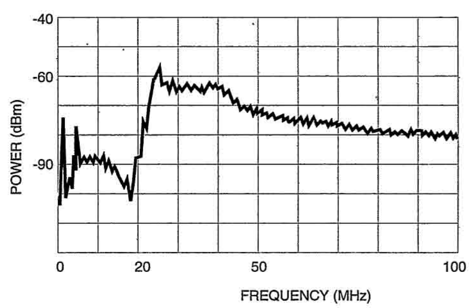


FIGURE 5 PIN DIODE SWITCH TRANSIENTS IN THE FREQUENCY DOMAIN THRU A HIGH PASS FILTER

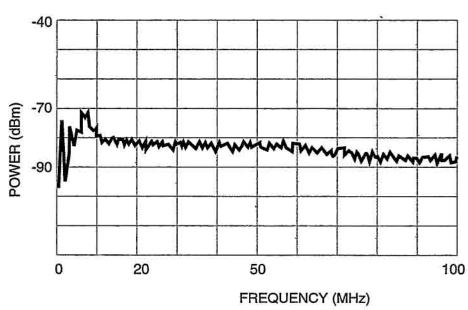


FIGURE 6 GaAs FET MMIC TRANSIENTS IN THE FREQUENCY DOMAIN

To illustrate, consider a SP2T switch with 1.0 dB insertion loss and a specification of 1.2 dB insertion loss maximum. This switch has 1.0 dB of insertion loss at power levels of up to +10 dBm where compression begins to take effect. At signal levels above +10 dBm, the signal begins to compress. This appears in the form of increased insertion loss. At a power level of +15 dBm, this switch has 1.0 dB of compression and 2.0 dB total loss. At this point, the insertion loss is well above the maximum specified value and the switch is in heavy compression.

In the previous example, the switch had 1.0 dB of compression at +15 dBm. Since the switch is operating in a very non-linear region at this power level, this is not a good specification for maximum operating power. With this in mind, consider the 0.1 dB compression point as a figure of merit for power handling. The 0.1 dB compression point for the switch in this example is approximately +12 dB. At this power level the switch would have 1.1 dB of insertion loss and would still meet its specified insertion loss of 1.2 dB maximum. The 0.1 dB compression point is a better measure of RF power handling, or maximum RF operating power, for low loss devices like RF switches. This is because the device is still essentially operating in a linear fashion and parameters such as insertion loss, VSWR and intercept points are unchanged from their small signal performance. In general, the 0.1 dB compression point is the maximum RF operating power at which the switch should be expected to meet all of the specified parameters.

Another RF power handling specification that should be considered is the NO DAMAGE power level (i.e. a maximum survivable power level). When this power level is applied, the switch may or may not meet the normal operating specifications but, once removed, the switch returns to normal operating parameters.

It should be noted that for PIN diode and MMIC switches, compression points and power handling are a function of frequency. The power handling of these devices dramatically improves above 100 MHz and declines sharply at lower frequencies. For example, a typical GaAs MMIC SP2T (P/N DS0602) has a typical 0.1 dB compression point of +11 dBm at 20 MHz and +23 dBm at 500 MHz. PIN diodes also exhibit a similar frequency dependent characteristic. However, by choosing diodes with large intrinsic regions and with proper biasing, PIN diode switches can handle very high power levels (up to several kW in special applications).

Intercept Points:
"The intercept is the extrapolation of the distortion power to the power level of the drive signals, assuming the switch has no compression of the signals. It is a fictitious power level, but gives a useful number from which distortion at any drive power may be computed."[2] If the intercept point is known, the level of the distortion products in relation to the fundamental signals can be calculated using the formula shown below.

$$SFDR = (n-1)\ (IPn - Pf)$$

[2] Distortion in p-i-n Diode Control Circuits, Robert H. Caverly and Gerald Hiller, IEEE Transactions on Microwave Theory and Techniques, Vol. MTT-35, No. 5 May 1987

The assumptions in this formula are:

The assumptions in this formula are:

1. There are two equal power input signals at frequencies f1 and f2 and at a power of Pf.
2. Both of the fundamental signals and the intermodulation product of interest (at frequency fs) fall within the passband of the device.

SFDR = Spurious Free Dynamic Range and is defined as the difference (in dB) between the fundamental signals and the nth order spurious signals.

n = nth order (2nd, 3rd, etc.) of the spurious response, n = A + B

A = the harmonic factor of the fundamental signal at frequency f1

B = the harmonic factor of the fundamental signal at frequency f2

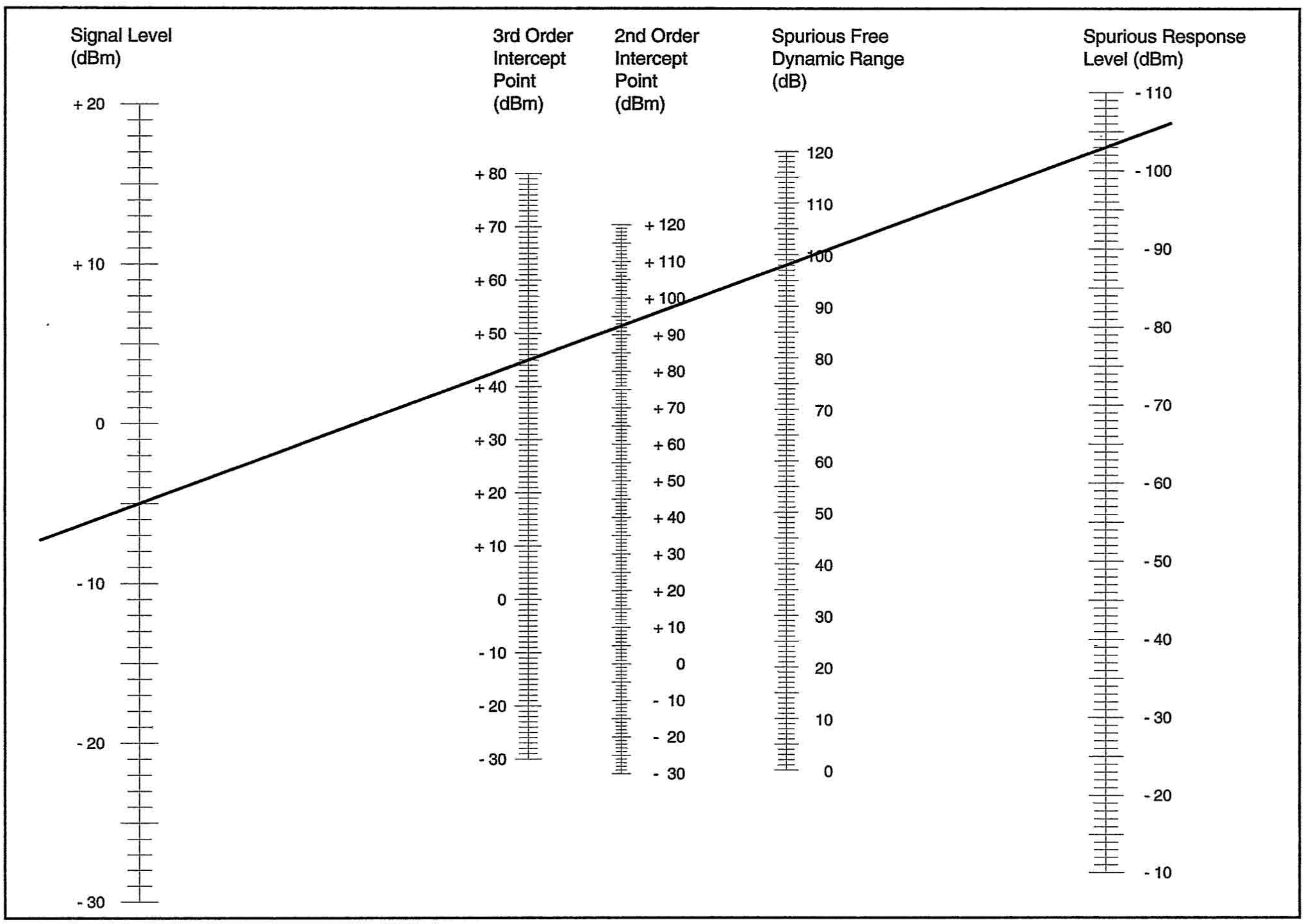
IPn = the nth order intercept point

Pf = the power (in dBm) of the fundamental signals (don't forget the sign)

fs = the frequency of the spurious response of interest

fs = [A x f1± B x f2] (absolute magnitude)

INTERCEPT POINTS



As an example, consider a device with a third order intercept point (IP3) of +44 dBm (DS0052, Table 1). In the presence of two -5 dBm signals at 225 MHz and 260 MHz (see Figure 7), the intermodulation performance of the device would be calculated as follows:

SFDR = (3 - 1){+44-(-5)} = 98 dB

f_s(lower) = [2 x 225-1 x 260] = 190 MHz

f_s(higher) = [1 x 225-2 x 260]= 295 MHz

In the example above, the SFDR is 98 dB. The absolute power of these intermodulation products (Pa) is calculated as follows:

Pa = Pf - SFDR = -5 dBm - 98 dB = -103 dBm

Figure 8 shows the actual intermodulation (spurious) performance of the device in the example above. The 190 MHz intermodulation product was actually measured at -110 dBm, or a SFDR of 105 dB. This equates to an IP3 of 47.5 dBm versus the typical IP3 of 44 dBm in Table 1. The intercept point nomogram can be used to simplify the calculations, and shows the relationships between signal level, intercept point, spurious free dynamic range and spurious response level.

A comprehensive discussion of distortion products is given in a paper by K.A. Simons.[3]

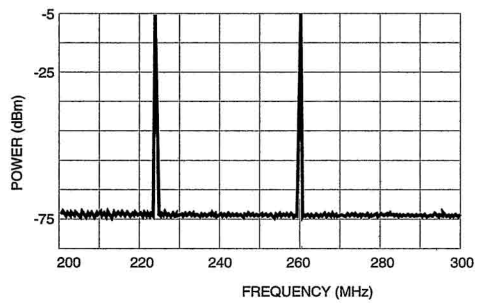


FIGURE 7 TWO INPUT SIGNALS

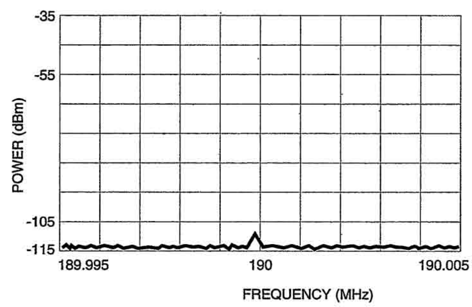


FIGURE 8 PIN DIODE SWITCH THIRD ORDER INTERMODULATION PRODUCT

It is usually assumed that intercept points are related to the frequency and the minority carrier lifetime in PIN diodes. Caverly and Hiller[4] have shown that the ratio of stored charge to diode series resistance is the driving factor in PIN diode distortion. This is proportional to the square of the ratio of lifetime of the carriers divided by the area of the intrinsic region. So for PIN diodes, the distortion is determined by the geometry of the diode as well as the DC control current and reverse bias voltage applied to the diodes.

Intercept point performance of MMIC switches is related to the physical geometry of the FET, the gate bias and frequency. Many GaAs FET MMIC's use a +5 V single sided supply, and float the MMIC at the supply voltage. A ground on the gate acts to pinch-off the FET in the MMIC. Figures 9, 10 and 11 show how the third order spurs (2f1 - f2) increase as the gate voltage Is lowered. For -8 V, the third order intermodulation signal (see Figure 9) is 65 dB below the carrier level, IP3=45.5 dBm; for a -5 V control, the intermodulation signal (see Figure 10) is 63 dB below the carrier level, IP3=44.5 dBm; but with the control at -4 V, the intermodulation signal (see Figure 11) is only -36.5 dB, IP3= 31.3 dBm. It is interesting to note that as the gate voltage was changed from -8 V to -5 V the third order intercept point decreased by only 1 dB, however, when the gate voltage was decreased to -4 V, the third order intercept was decreased by 13.2 dB. Figure 11 also shows the growth of the fifth order intermodulation product (-47.5 dB below the carrier).

As with compression points, intercept points of MMIC and PIN diode switches are frequency dependent and improve substantially at higher frequencies.

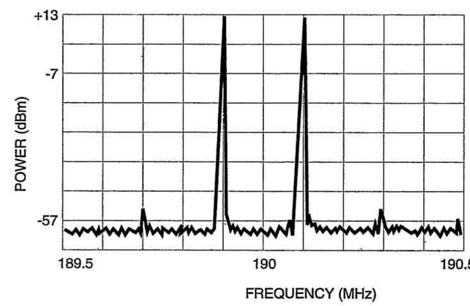


FIGURE 9 MMIC SWITCH THIRD ORDER INTERMODS; GATE VOLTAGE = -8V

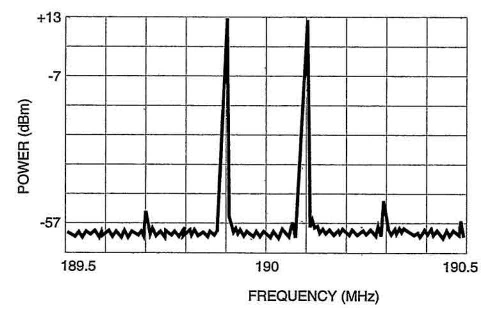


FIGURE 10 MMIC SWITCH THIRD ORDER INTERMODS; GATE VOLTAGE = -5V

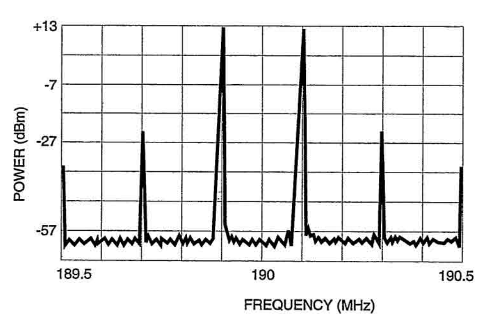


FIGURE 11 MMIC SWITCH THIRD ORDER INTERMODS; GATE VOLTAGE = -4V

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[3]The Decibel Relationship Between Amplifier Distortion Products, Kenneth A. Simons, Proceedings of the IEEE, Vol. 5B, No. 7, July 1970.

[4]Distortion in p-i-n Diode Control Circuits, Robert H. Caverly and Gerald Hilles, IEEE Transactions on Microwave Theory and Techniques, Vol. MTT-35, No. 5 May 1987

Phase & Amplitude Tracking and Matching:
Phase and amplitude tracking/matching specifications are especially important on multi-throw switches since, depending upon the design of the device, the individual throws can have different electrical lengths and losses. This will result in different phase and amplitude characteristics for each throw. Good phase and amplitude tracking or matching can be achieved on most switches if the requirement is identified initially and the switch is designed with this in mind. Although phase or amplitude tracking and matching may appear to be the same thing, they are actually quite different. Tracking refers to how well the throws (ports) follow one another with regard to amplitude or phase across frequency or temperature (or both). Or to state this in equation form:

$$\text{Phase}_{\text{port1}} - \text{Phase}_{\text{port2}} = \text{constant}$$

$$\text{Insertion Loss}_{\text{port1}} - \text{Insertion Loss}_{\text{port2}} = \text{constant}$$

Since this specification requires only that the difference remain constant, it is possible to have different insertion phases (or losses) for each port.

Matching refers to how well the throws match one another with regard to an absolute insertion phase (or loss) at a given frequency. In this case, each port will have the same insertion phase (loss) within a specified tolerance (i.e. +/-1 degree). So for this case:

$$\text{Phase}_{\text{port1}} = \text{Phase}_{\text{port2}} \pm \text{specified tolerance}$$

Yet another tracking/matching specification is that of tracking or matching switches in sets or to a golden (standard) unit. If the system requires that multiple channels have similar insertion phase (loss) characteristics then the system designer should specify the switches in sets of X. Where each switch in the set will have the same insertion phase (loss) within a given tolerance. On the other hand if the system requires that each channel track be in phase (loss), but the absolute insertion phase (loss) is not critical, then tracking in sets of X should be specified.

Switches can also be specified to match a golden (standard) unit. In this case, all units built must match the reference unit. While this sounds very attractive on the surface, this can be difficult to achieve and maintain on long (multi-year) production runs since the variations in the characteristics of the components and manufacturing processes can cause the insertion phase (loss) to vary over a period of time.

With these subtle but important parameters in mind, lets compare the advantages and disadvantages of each technology as well as some of their idiosyncrasies.

SWITCH TECHNOLOGIES

Mechanical Relay Switches:
Mechanical relays are a mature technology which feature excellent insertion loss, power handling and isolation, while avoiding the concerns of compression points or intermodulation products. However, two notable weaknesses of mechanical relays are 1) switching time - which is on the order of 2 milliseconds, and 2) limited switch operating life - which for a MIL-R-39016/9 relay is 10,000,000 cycles. For many applications this will result in a operating life of several decades, however, in applications requiring frequent switch cycling the life expectancy is substantially reduced. One other point to keep in mind is that relays require relatively large coil operating power, typically 400 mW per relay. For applications with low cycle rates or infrequent switching and where DC power is abundant and insertion loss is of paramount concern, relays are still an excellent choice.

Schottky Diode Switches:
Schottky diodes have excellent switching speed and very low transients when used in high speed balanced designs. Transition times of less than 5 nanoseconds and transients on the order of 15 to 25 mV are typical (see Table 1). This is directly related to the small amount of stored charge in the forward bias state of Schottky diodes. This charge can be quickly swept out of the depletion region during switching.

The most significant disadvantages of Schottky diodes in switch applications are the high junction capacitance (which limits bandwidth and isolation) and the relatively large amount of DC current consumed. Large DC currents are required to achieve a low series resistance, and, because it is modulated by the RF signal, it must exceed the peak RF current. Hence power handling is limited, but is not a function of frequency as is the case with PIN diode and MMIC switches. Schottky diode switches also exhibit slightly higher insertion loss than PIN diode and MMIC switches (see Table 1). Typical values for the DC current of a SP2T Schottky switch range from 150 to 200 mA (see Table 1).

PIN Diode Switches:
PIN diodes are the workhorse of the RF switch industry. They exhibit low insertion loss when forward biased and good isolation when reverse biased, as well as excellent bandwidth performance (see Table 1). Consider a PIN diode which has a series resistance of 1.5 ohms at a forward bias current of 3 mA. This results in an insertion loss of roughly 0.15 dB per series diode and 26 dB of isolation per shunt diode. When reversed biased, the junction capacitance is 0.2 picofarads, resulting in over 20 dB isolation per series diode at frequencies below 3 GHz and an insignificant contribution to insertion loss by the shunt diode. These features combined with excellent power handling make the PIN diode a versatile building block for the RF switch designer.

SWITCH COMPARISON TABLE
Table 1

		SCHOTTKY DS0252	PIN DS0052	MMIC DS0602	RELAY 100C1003
TRANSITION TIME	nS	5	80	4	-
SWITCHING SPEED	nS	20	280	26	2 mS
INSERTION LOSS (250 MHz)	dB	0.9	0.6	1.3	0.15
ISOLATION (250 MHz)	dB	62	72	52	75
TOTAL CURRENT	mA	180	15	0.15	92
SUPPLY VOLTAGE		+5	+5	+5	+12
TRANSIENTS	mV	15	780	100	-
INTERCEPT 2ND	dBm	+75	+72	+53	-
INTERCEPT 3RD	dBm	+35	+42	+37	-
POWER HANDLING 0.1 dB COMP. @ 250 MHz	dBm	+12	+24	+22	+45 MAX
BANDWIDTH	MHz	2-400	10-2000	5-2000	DC-1200

(TYPICAL DATA FROM GRAPHS 1 THRU 4)

The main disadvantage of PIN diodes switches is relatively slow switching speed. This is caused by 2 factors. One factor is the time required for charge to be swept out of the intrinsic layer of the diode, which can range from 10 nanoseconds to over 1µs. However, the primary cause for slow switching speed is that the control current must be fed into the RF path through a reactive network that will pass the control current but reject the RF signal. This reactive network limits the rise time of the control signal and thus limits the transition time of the diodes. If the cutoff frequency of the control network is increased to allow the diode bias current in more quickly to achieve a faster transition time, the low frequency insertion loss will be increased. This is due to the shunt effect of the control network on the RF signal path. Because of this effect, the cutoff frequency of the control feed network must always be well below the lower RF frequency limit of the switch (usually a factor of 5 to 10) in order to maintain good VSWR and insertion loss in the RF pass band as well preserving the RF/Control isolation.

MMIC GaAs FET Switches:
MMIC switches are the latest technology and come with impressive performance parameters. MMIC's have switching speed and transitions times comparable to Schottky diodes, typically 20 nanoseconds and 5 nanoseconds respectively, excellent transient performance and the good bandwidth characteristics of PIN diodes (see Table 1). Unlike Schottky diodes, MMIC's achieve excellent switching characteristics while requiring extremely low current levels (less than 1 milliampere typically for switches complete with drivers). Most of the current consumption is used by the driver circuitry and not the MMIC itself, which consumes typically 10 microamperes. In MMIC's, the RF through-path is separate from the gate control lines[5], i.e. these signals do not travel in the same circuit path unlike PIN diode switches. Hence, the MMIC switches can be driven at faster rates without being limited by RF signal leakage onto the control line.

MMIC's however are not the panacea sought by the RF switch designer. They exhibit slightly higher insertion loss than diode switches and are relatively inflexible in designs. The MMIC's lack of design flexibility is due; in part, to the relative infancy of the technology itself and the high cost of changing a MMIC design. For example, in a diode switch the insertion loss can be reduced by increasing current flow through the diode or selecting a different diode. In MMIC switches, the monolithic devices have fixed parameters (i.e. isolation and insertion loss) and configuration (i.e. SPST, SP2T, etc.). These parameters cannot be improved by the circuit implementation. For example, at a given frequency, if 5 dB more isolation is required from a MMIC switch with 55 dB isolation, the designer must add another series

[5]Using MMIC's as Control Devices, Raymond Pengelly, Microwave Systems News, April 1989

MMIC (or spend substantial NRE for a new mask set) resulting in 20 dB more isolation along with an additional 1 dB typical insertion loss, (or a new MMIC design which generally is very expensive and takes several months to implement). In diode switches, an additional diode shunt on the RF path can easily add the needed 5 dB isolation, while adding only 0.1 dB more insertion loss. Diodes allow greater flexibility to achieve customized design goals, whereas, limited by large development costs, MMIC switches are designed to meet generalized switch needs very well, giving far less support to specific applications.

One other note: MMIC's do not switch completely off (i.e. reach the isolation state) as fast as might be expected. The signal goes from 100% to under 10% (or from 0 to 95%) in the transition time specified, typically 5 nanoseconds, but lingers at 2-3% level of full signal strength. This extended settling time can stretch out, in some cases, for 100 nanoseconds or more. There is no firm explanation for this phenomena as yet, however, speculation centers around surface state trapping in the nitride dielectric layer that insulates the gate from the source/drain metallization. This phenomena varies from lot to lot, but the smallest amount of lingering can be troublesome in high speed blanking switch applications, where insertion loss, insertion phase, and isolation will not be settled (at a final value) for up to 100 nanoseconds or more.

Comparing Switch Tradeoffs within a Technology

Within each technology, the building block (i.e. Diodes, FETs relays, etc.) can be optimized to achieve certain performance goals. This is done using tradeoffs which enhance one performance characteristic, while degrading another. For example, Daico P/N DS0800 is a SP2T switch that has been optimized for high intercept point performance and power handling (see Table 2 and Graph 5). To achieve this, PIN diodes with larger intrinsic regions were used. The result is a switch with excellent intercept performance and power handling. The trade, however, comes at the expense of the slower switching speed and increased switching transients. Table 2 compares the performance of the DS0800 with that of a general purpose SP2T PIN diode switch DS0052 (see Graph 2).

MMIC's can also be optimized for specific performance features. Consider Daico P/Ns DS0842 and DS0602. The DS0842 has been optimized for insertion loss and isolation at the expense of switching speed and a small amount of current (see Table 2 and Graph 6). The DS0842 uses a MMIC with longer gate lengths than the MMIC used in the general purpose DS0602. The longer gate lengths result in lower insertion loss and increased isolation of the switch but the penalty is slower switching speed: 50 nanoseconds for the DS0842 versus 26 nanoseconds for the DS0602 and less bandwidth.

So through careful selection of the key parameters, an RF switch can be optimized to achieve the critical parameters for specific applications.

The effects of the lesser known switch parameters on the overall systems performance should be evident from this discussion of transients, intercept points, RF power handling, and transition time versus switching speed. During the component selection stage of your RF system design, never forget that a switch is more than just a few series and shunt diodes or a MMIC. It is an integral part of your overall system. Selecting the right RF switch can be the difference between marginal system performance and meeting the intended goals!

SIDE BAR:

Switch Technology Comparison:

By way of comparison, Table 1 lists the performance characteristics of broadband SP2T switches representative of each of the four technologies. Graphs 1 through 4 show the insertion loss, VSWR and isolation of the same switches. Examination of the PIN diode switch (Daico P/N DS0052) and the MMIC switch (P/N DS0602) shows that although the MMIC operates over a broader bandwidth, the MMIC has slightly higher insertion loss and lower intercept points while consuming less than one percent of the power. The switching speed for the MMIC is much faster; 25 nanoseconds versus 280 nanoseconds for the PIN diode switch and the transients generated by the MMIC switch are much lower than for the PIN diode switch (100 mV vs 780 mV). This clearly illustrates the advantage of the MMIC switches in the areas of switching speed and current consumption as well as its drawbacks of slightly higher insertion loss and reduced intercept point performance.

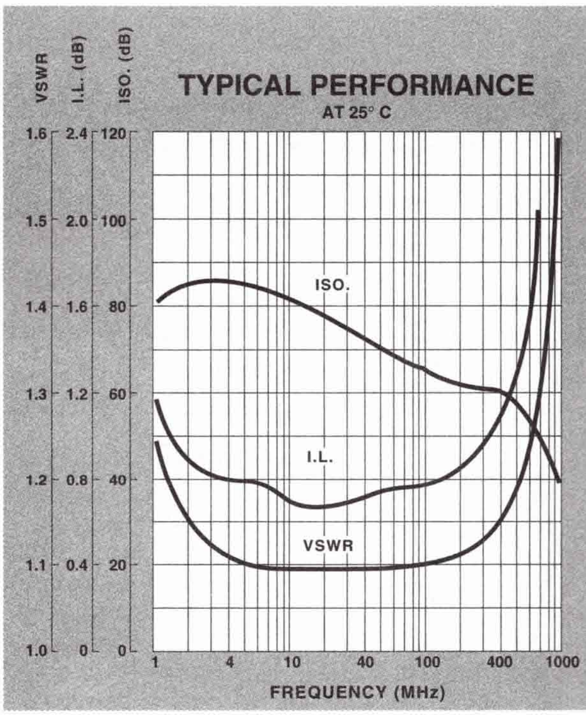
The Schottky switch (P/N DS0252) has a relatively narrow band compared to the PIN and MMIC devices, operates to only 400 MHz, but switches in the same 25 nanoseconds as the MMIC switch. It is also interesting to note that schottky switch draws over 1000 times the power of the MMIC device without any substantial benefit.

The relay switch (P/N 100C1003) operates to 1200 MHz with very low insertion loss and excellent power handling, but as with the Schottky device, requires a great deal of power. The switching speed of the relay, 2 milliseconds, is very slow as compared to any of the solid state devices which range from a few microseconds to 25 nanoseconds.

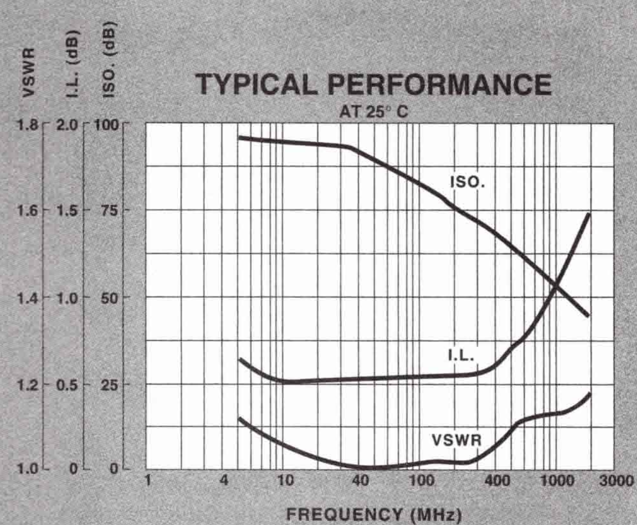
SWITCH COMPARISON TABLE
Table 2

		PIN DS0800	PIN DS0352	MMIC DS0602	MMIC DS0842
TRANSITION TIME	nS	12000	80	5	40
SWITCHING SPEED	nS	20000	280	25	50
INSERTION LOSS (250 MHz)	dB	0.8	0.6	1.1	0.8
ISOLATION (250 MHz)	dB	72	72	60	80
TOTAL CURRENT*	mA	53	15	0.15	0.6
SUPPLY VOLTAGE		+5, +15, -5	+5	+5	+5
TRANSIENTS	mV	2500	780	100	25
INTERCEPT 2ND 3RD	dBm dBm	+106 +57	+72 +42	+53 +37	+69 +50
POWER HANDLING 0.1 dB COMP. @ 250 MHz	dBm	+40	+24	+22	+22
BANDWIDTH	MHz	1-250	1-2000	5-2000	5-1500

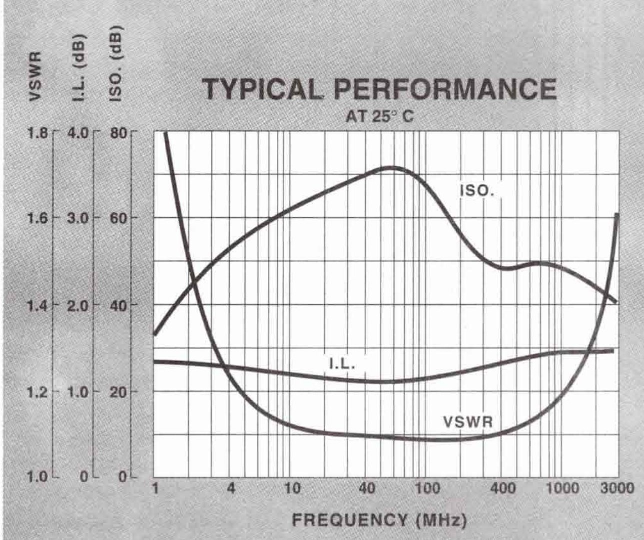
(TYPICAL DATA FROM GRAPHS 2, 3, 5, 6)
*TOTAL CURRENT, SUMMED FROM ALL SUPPLY VOLTAGES



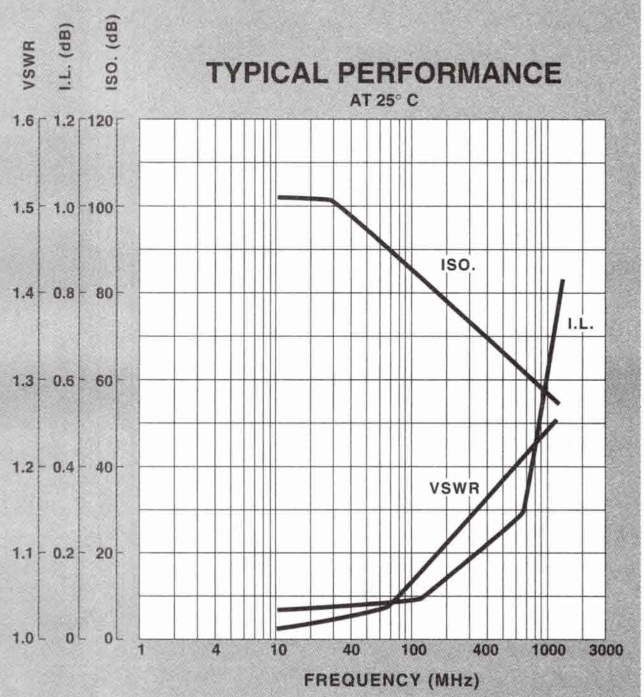
GRAPH 1
DS0252



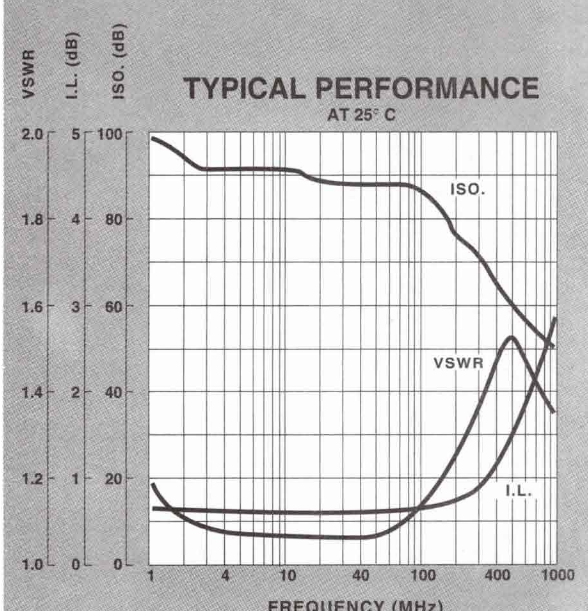
GRAPH 2
DS0052



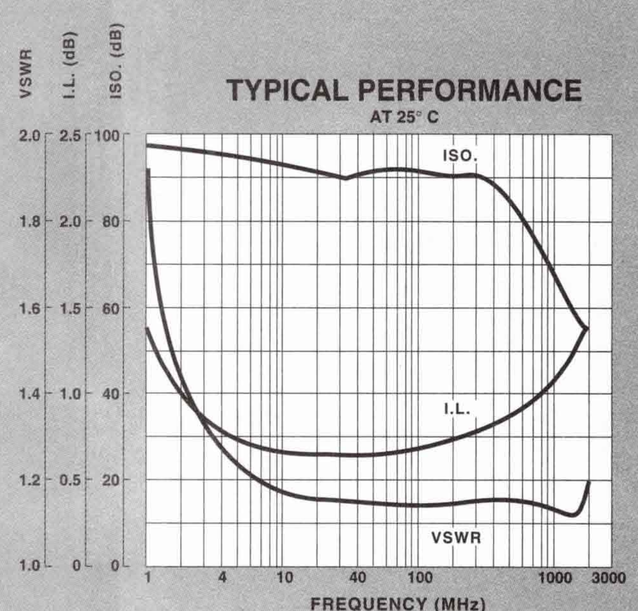
GRAPH 3
DS0602



GRAPH 4
100C1003



GRAPH 5
DS0800



GRAPH 6
DS0842