SWITCHING CHARACTERISTICS OF LATCHING FERRITE DEVICES

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Abstract

Switching characteristics of latching ferrite devices are discussed and it is shown that the switching time may be defined in several ways, depending on the application of the device. The interdependence of the switching time specification with several other pertinent variables, such as driver cost, switching energy, and bandwidth, is discussed.

Introduction

In both latching circulators and phase shifters, the microwave ferrite is shaped to provide a closed path for its magnetization. The change in state of the device is then accomplished by switching the magnetization of the ferrite around all or part of its hysteresis loop. It is apparent, then, that the switching time might be defined as that time necessary to cause the magnetization to change from, say, its negative remanent state to its positive remanent state, since the characteristics of the microwave device will have changed from some set of fixed values for the negative remanent state to another set of fixed values for the positive remanent state. This definition may be called the "total switching time", with the implication that other definitions of switching time are also useful.

Constant Voltage Switching

The most common technique for switching a latching ferrite device consists in the application of a "constant" voltage pulse to the latching wires; a charged capacitor supplies the current through a transistor which is turned on for a short time, the duration of the pulse, and the capacitor is selected so that its voltage does not change appreciably during the short discharge period. In such a case the current waveform is that depicted in Figure 1, which also shows the resulting change in magnetization as a function of time. During this switching operation the magnetization changes continuously (but not monotonically) from its initial state to its final state, and the pertinent microwave parameters of the device change continuously (but not necessarily monotonically) from their initial values to their final values.

Threshold Switching Time

For a given device, the application may be such that a useful definition of switching time can be made in terms of selected microwave performance characteristics. For example, in the application of a 3-port latching circulator as a SPDT switch, it is often sufficient to know the length of time after application of the switching pulse required for the attenuation in a given path to change from its low insertion loss value to some given value of isolation, say 20 db, and remain greater than that value thereafter. The latter words are important to this definition, as reference to Figure 1 will suggest. Since the isolation is a function of magnetization, the isolation may well become very high and then drop again below specification as the magnetization becomes too high, only to rise again to within specification as the magnetization drops to its final value. This characteristic is illustrated by Figure 2 which represents the performance of a latching circulator at 12 GHz. Here the switching time is 0.32 microsecond if the specified isolation threshold is 15 db. However, it is 0.7 microsecond for a 20 db threshold. The "total switching time" in this case is 0.8 microsecond. Clearly, the actual "threshold switching time" may be a function of frequency and temperature in a given circulator.

Other definitions of switching time are possible, such as the 10% to 90% switching time, provided the parameter whose percentage is being taken is specified, and provided the concept of threshold (the question of whether the parameter remains beyond 90% after passing it) is considered. Generally speaking, the application must be known, with its resulting requirements on microwave performance, before a clear and accurate statement can be made of the minimum switching time. However, the use of the "total switching time" as a specification, where adequate, is unambiguous for all applications.

Trade-Offs

The switching time is reduced by application of higher drive voltages and there are further trade-offs between higher switching speed and switching energy, driver cost, microwave bandwidth, and certain other pertinent parameters in a given case. Thus a number of judgements and assumptions must be made when attempting to show the switching speed for latching circulators as a function of frequency, as is done in Figure 3. This figure represents a reasonably conservative estimate of the "total switching time" when using relatively inexpensive drivers for circulators with moderately good bandwidth.

The total switching energy, representing losses in the driver and in the ferrite, is also subject to variations in particular cases, so that a curve of switching energy versus frequency as given also in Figure 3 represents some judgement; here again the numbers are reasonably conservative.

In the full paper the trade-offs between switching speed and energy, driver costs, transistor limitations, and bandwidth are treated more quantitatively.

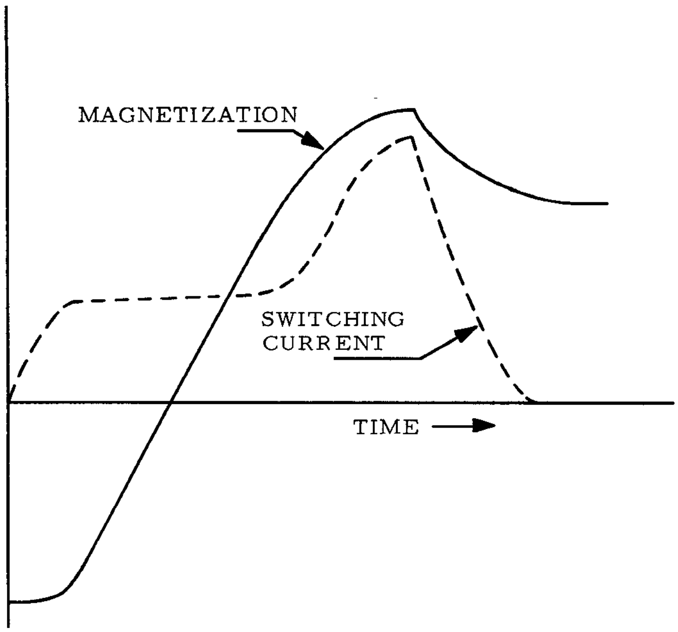

Fig. 1 Qualitative representation of magnetization and switching current versus time for "constant voltage" switching.

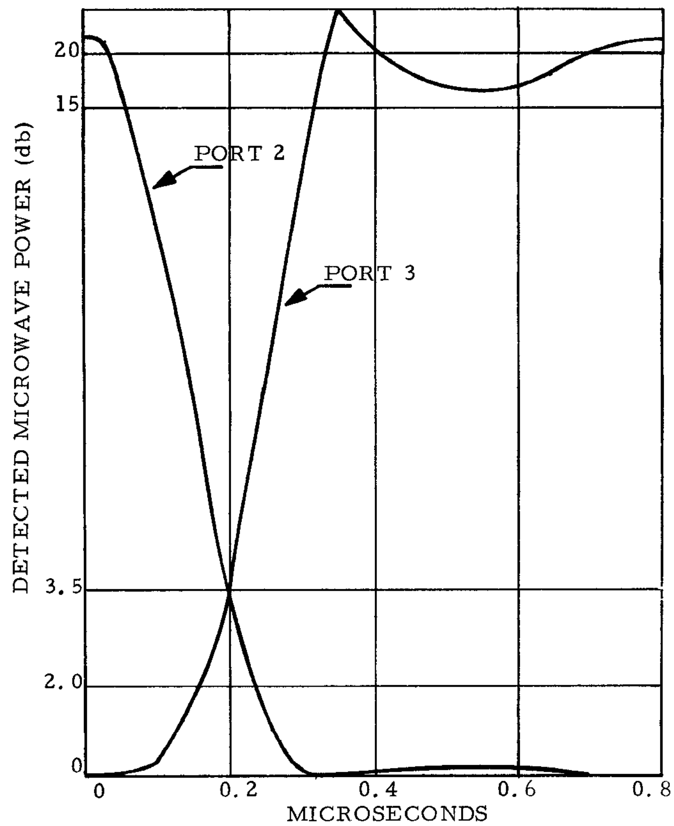

Fig. 2 Change of attenuation at two output ports of a 3-port latching circulator during switching operation.

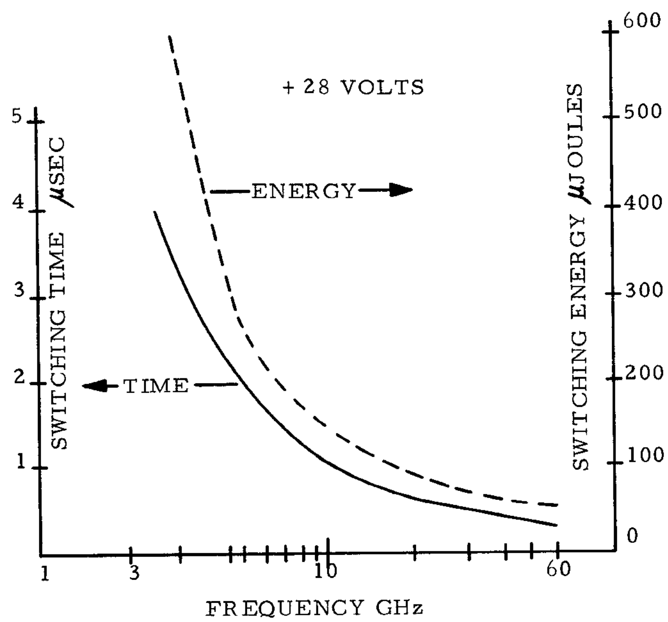

Fig. 3 Total switching time and total switching energy (including driver losses) for 3-port latching circulators.