# TWO MICROWAVE COMPLEX WEIGHTING CIRCUITS

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## SUMMARY

Two types of complex weighting circuits were implemented for use in adaptive phased array antennas. The first is an S-band circuit using p-i-n diodes. The second is an active X-band circuit using dual-gate GaAs FET's. A comparison of the two is presented with experimental data.

## INTRODUCTION

Adaptive phased array antennas have an important role in electronic warfare. An integral part of such antennas is the complex weighting circuit. These circuits can vary the amplitude and phase of RF signals, canceling unwanted interference. Complex weighting circuit operation and applicable specifications are examined, and two schemes of implementation are compared.

## S-BAND WEIGHT

A vector representation of the S-band complex weight circuit operation is shown schematically in Figure 1. A signal of arbitrary phase and magnitude is split into its in-phase and quadrature components by the 3-dB quadrature hybrid. The attenuator varies the magnitude of the vectors along the in-phase and quadrature axes. The phase shifter flips the vectors 180° out-of-phase. The two signals are then summed in the power summer circuit, giving a signal vector of any arbitrary phase and magnitude. The full range of vectors available are located in the complex plane as shown in Figure 2.

Several important performance parameters are associated with the various circuits used in a complex weight; these determine how accurately the weight is able to reproduce the complex plane. These parameters include:

- The dynamic range of the attenuator circuit.
- The insertion phase change with attenuation.
- The phase error associated with the 0/180° phase shifter.
- The phase and amplitude errors associated with the quadrature hybrids.

The S-band complex weight circuit utilizes the basic block diagram given in Figure 1. A Lange interdigital quadrature hybrid coupler(1) is used with a Wilkinson type power summer.

The variable attenuator is two stages of a p-i-n diode Tee attenuator.(2) Its attenuation and phase characteristics are given in Figures 3 and 4. A p-i-n diode-controlled switched-line phase shifter is used for the 0/180° bit. Figure 5 is a photograph of the S-band complex weight module which includes a 20.5 dB gain, 3.5 dB noise figure low noise amplifier.

Some of the S-band weight circuit performance parameters are listed in Table I. Figure 6 depicts how accurately the circuit reproduces the complex plane. Deviations from ideal are due to the previously mentioned phase and amplitude errors. An additional 20 dB attenuation can be obtained by reverse biasing the diodes in the 0/180° phase shifter.

TABLE I
S-BAND COMPLEX WEIGHT PERFORMANCE

| | |
|---|---|
| Frequency | 2200-2300 MHz |
| Variable Attenuation Range | 30 dB |
| Attenuation Flatness with Frequency | ±0.05 dB |
| Insertion Loss (One channel activated) | 10.9 dB |
| Return Loss (All Ports) | 14 dB |
| Phase Change with Attenuation | 32° |

## X-BAND WEIGHT

The X-band complex weight circuit is depicted in Figure 7.(3) This circuit, which utilizes a dual-gate GaAs FET variable gain amplifier/attenuator and no phase shifters, was implemented at X-band frequencies. The proper phasing is accomplished by the relative phases of the Lange quadrature hybrids.

One of the advantages of this type of circuit is its ability to provide gain to offset its loss, thereby reducing the requirements for amplifiers elsewhere in the system. Also, by properly terminating the second gate of the dual-gate GaAs FET, phase variation with amplitude is minimized.(4) Phase errors comparable to those obtained for the S-band circuit can be realized. In addition, the phase errors of the switched line-type phase shifters are eliminated by using broadband quadrature hybrids.

The dual-gate GaAs FET amplifier phase and amplitude characteristics are given in Figures 8 and 9. The performance of the X-band complex weight circuit is summarized in Table II. The accuracy in reproducing the complex plane is shown in Figure 10. A photograph of the X-band complex weight breadboard is presented in Figure 11.

TABLE II
X-BAND COMPLEX WEIGHT PERFORMANCE

| | |
|---|---|
| Frequency | 7000-8000 MHz |
| Insertion Loss* | 6.4 dB |
| Gain Flatness | ±0.5 dB |
| Attenuation Range | 25 dB |
| Phase Change Over Attenuation Range | 48° |

*Includes 7 dB gain of dual-gate GaAs FET amplifier with one channel activated.

REFERENCES

1. Lange, J., "Interdigitated Stripline Quadrature Hybrid", IEEE Trans. Microwave Theory and Techniques, Volume MTT-17, pp. 1150-1151, December 1969.

2. Parris, W.J., "P-I-N Variable Attenuator with Low Phase Shift", IEEE Trans. Microwave Theory and Techniques, Volume MTT-20 pp. 618-619, 1972.

3. Granatasio, J.B. Schappacher, D., Scott, G., and Williams, M.R., "S-Band Complex Weight Module for Adaptive Processing", NASA Tech Brief LAR-12197.

4. Liechti, Charles A., "Performance of Dual-Gate GaAs MESFET's as Gain-Controlled Low-Noise Amplifiers and High-Speed Modulators", IEEE Trans. Microwave Theory and Techniques, Volume MTT-23, pp. 461-469, 1975.

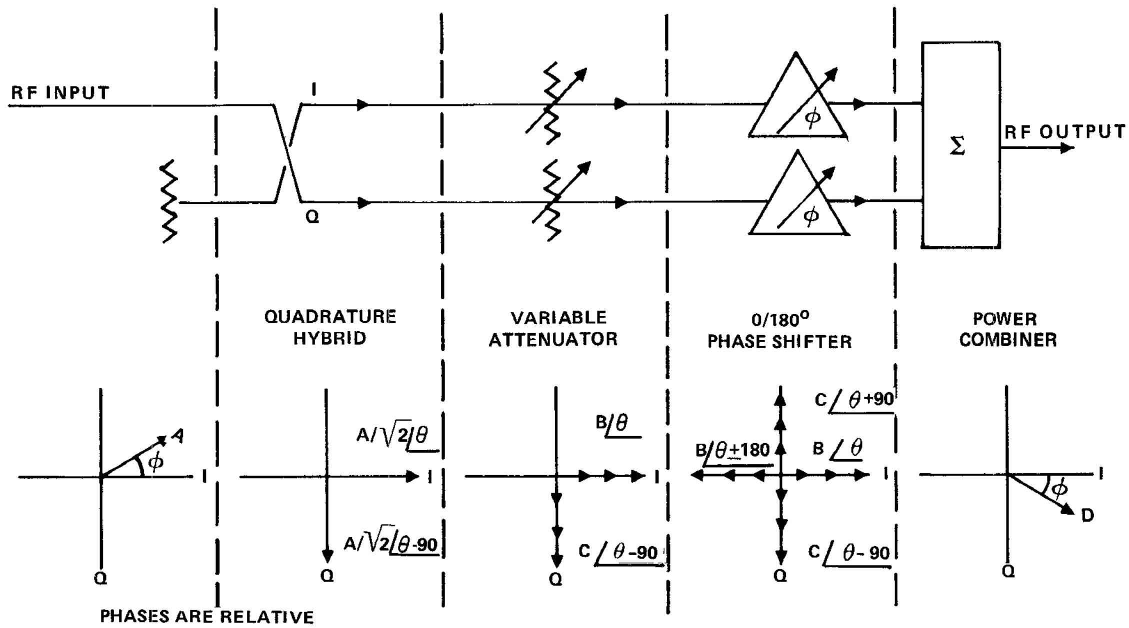


Figure 1. A Vector Representation of How a Complex Weighting Circuit Works

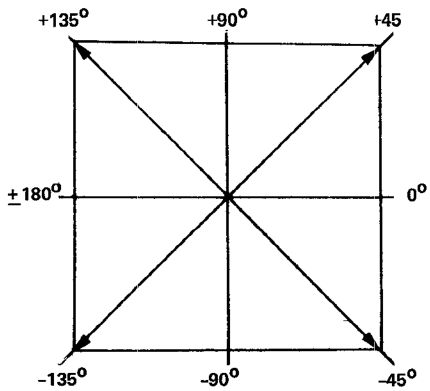


Figure 2. Complex Plane

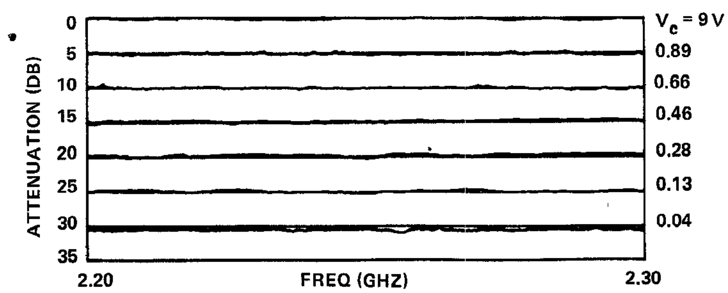


Figure 3. S-band Attenuator Characteristics (Attenuation)

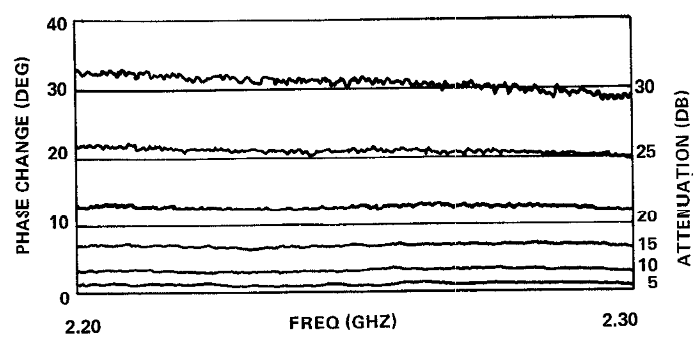


Figure 4. S-band Attenuator Characteristics (Phase)

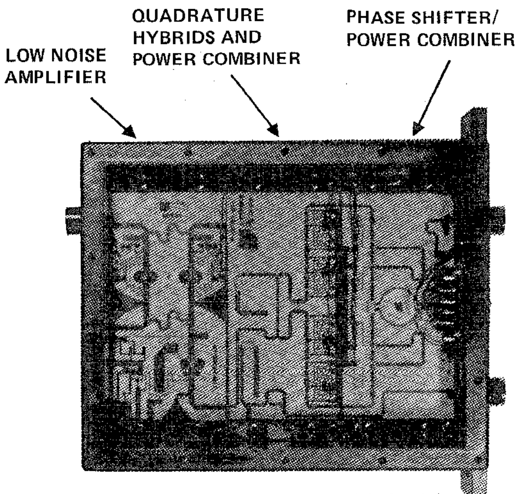


Figure 5. S-band Complex Weight Module

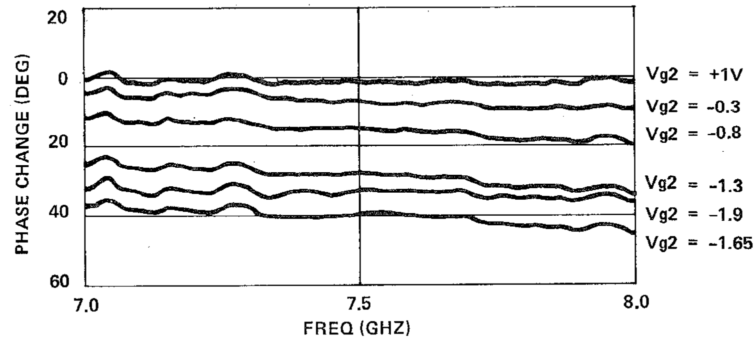


Figure 8. X-band Dual Gate GaAs FET Amplifier Phase Characteristics

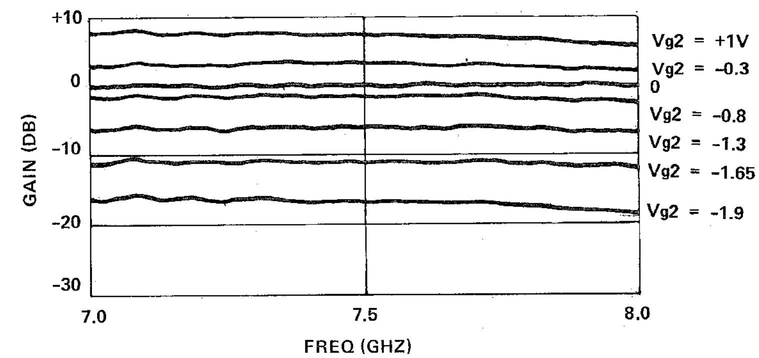


Figure 9. X-band Dual-gate GaAs FET Amplifier Gain Characteristics

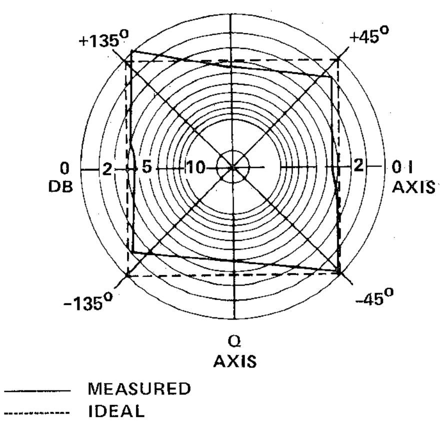


Figure 6. S-band Complex Plane Measurements

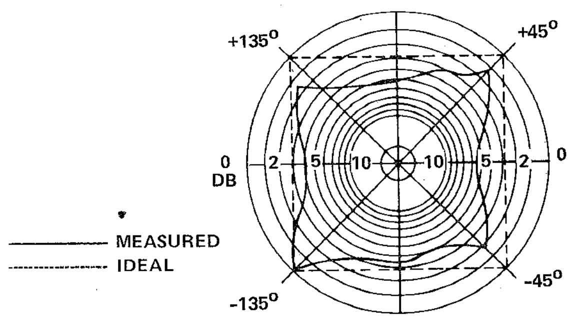


Figure 10. X-band Complex Plane Measurements

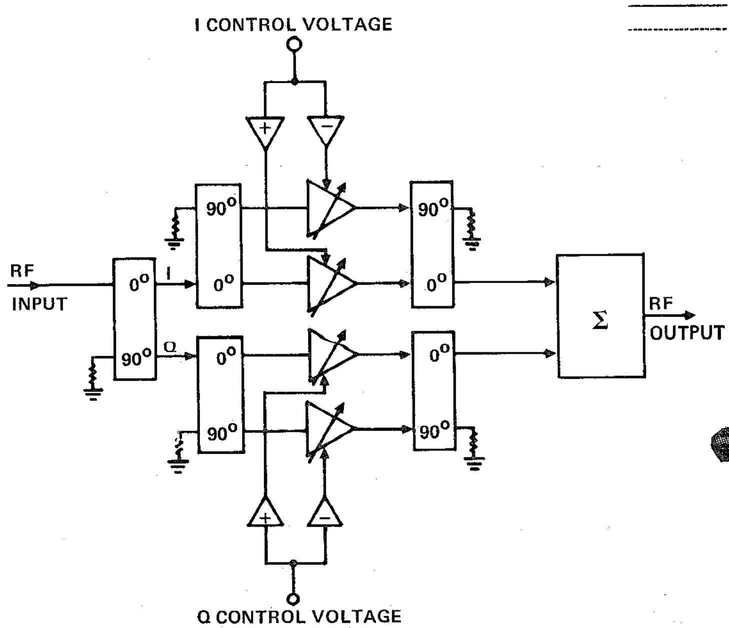


Figure 7. X-band Complex Weight Block Diagram

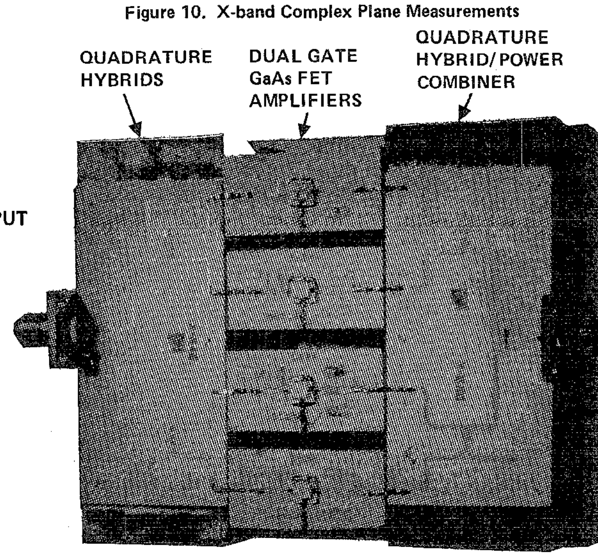


Figure 11. X-band Complex Weight Breadboard