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# **Metamaterial Based Vacuum Electron Devices for Next Generation Communication Systems**

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**(In collaboration with Tufts University)**

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# Outline

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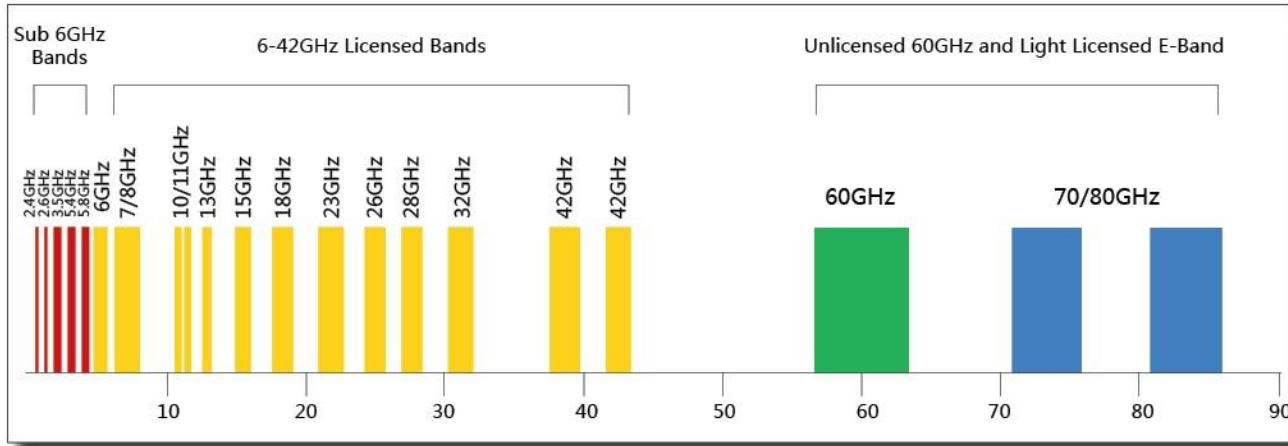
- **Motivation**
- **Phase I Work**
- **Phase II Proposal**
- **Phase II Product Development**
- **Conclusions**

# Motivation

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- **Harness unique properties of Metamaterial structures for mode and frequency control in Vacuum Electron Devices (microwave tubes)**
- **Mode and frequency selectivity will lead to gains in spectral purity of the devices**
- **Develop a 5W Traveling Wave Tube (TWT) for high data rate communication application**

# TWT For Long Range E-Band Radios



- **60/70 GHz unlicensed and light-licensed bands for wireless backhaul applications**
- **Current radios use solid-state sources with ~0.3 W of power**
- **Develop a TWT with 16 X higher power and 10 GHz bandwidth to cover the full band**

# Advantages of a TWT Solution

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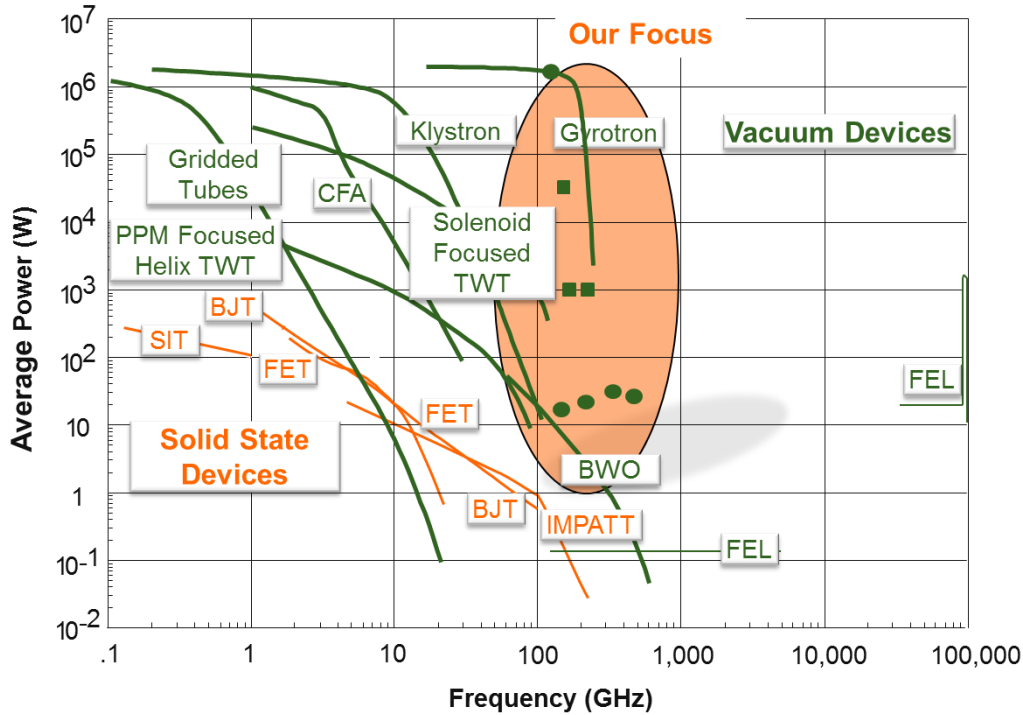
- **Generate the maximum allowed power ~5W with a single device**
- **~ 16X higher power  $\Rightarrow$  ~ 4X longer range**
- **Long range direct link**
  - 2 radios for a direct link instead of 8 for serial link
  - Cost savings ~ \$100,000
  - Lower latency
  - Lower maintenance costs

# Outline

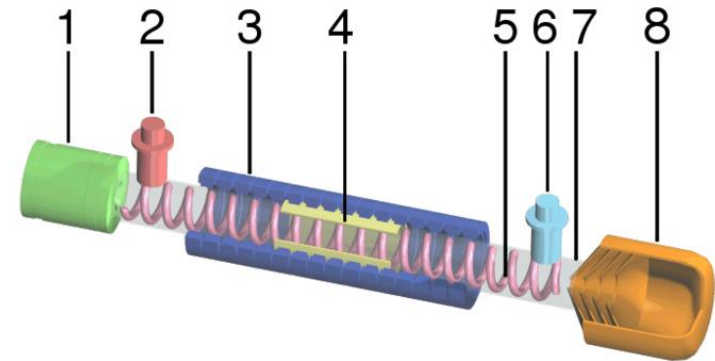
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# Why Microwave Tubes?



Source: Google Images



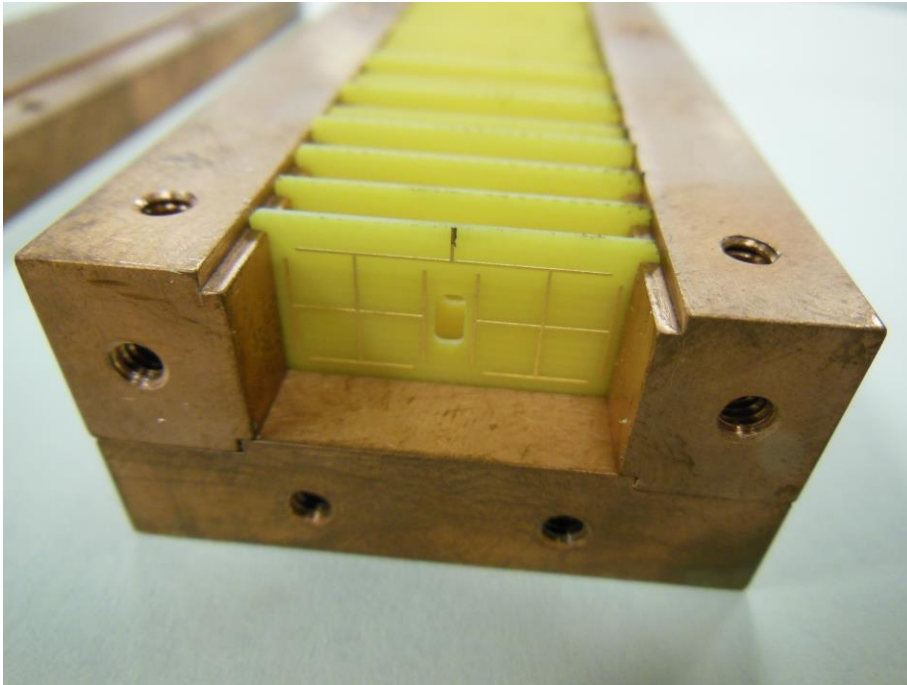
# Metamaterial (MTM) Structures for Vacuum Devices

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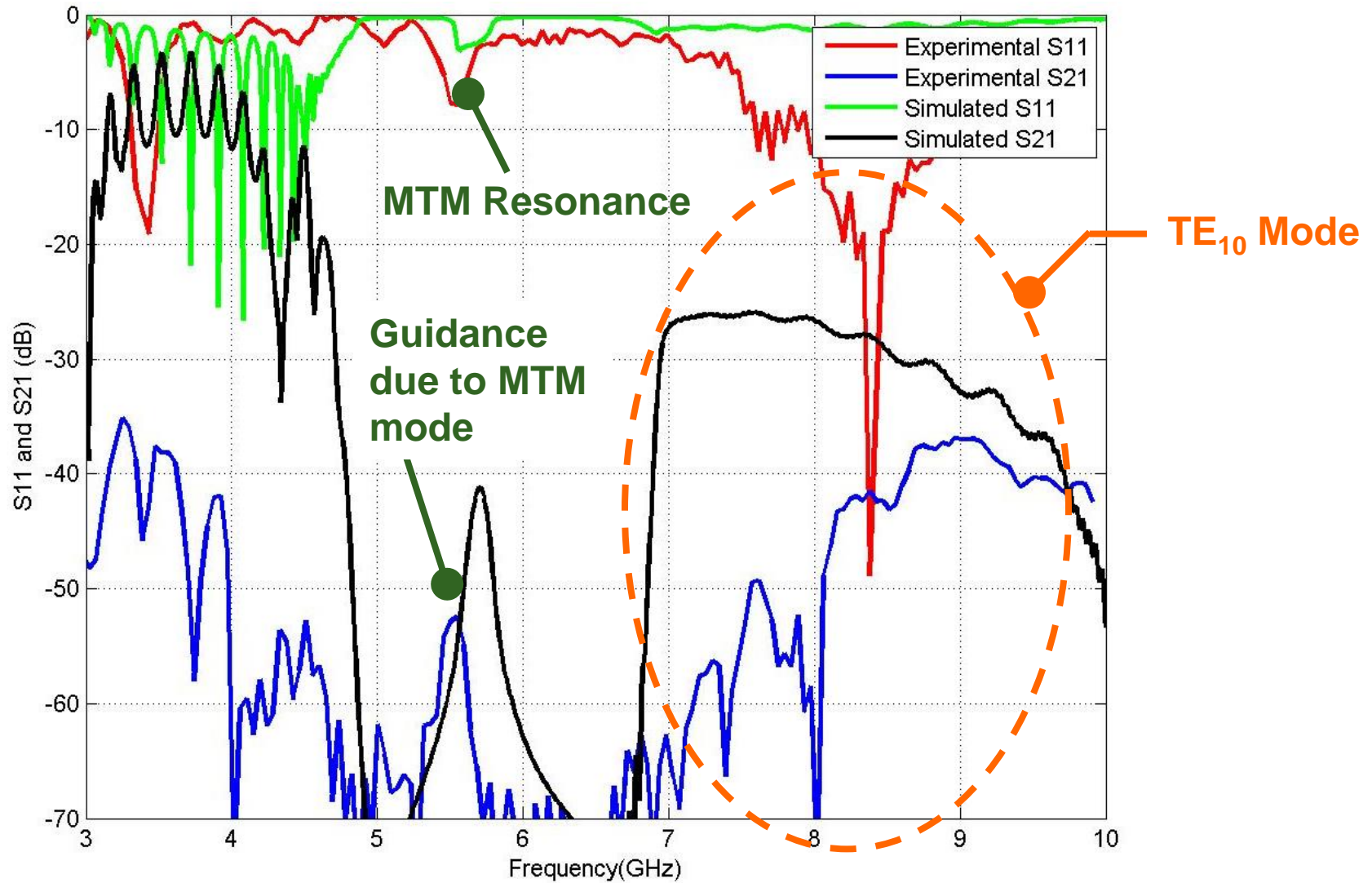
- **MTM consists of subwavelength structures with a strong electric or magnetic response**
- **The effective medium can have combinations of positive and negative permittivity and permeability**
- **Application of MTMs in Vacuum Electron Devices**
  - Use high  $\mu$  and  $\epsilon$  to create slow waves in specific frequency band
  - Tuned dual frequency absorbers to suppress band edge oscillations in TWTs and other vacuum devices



# MTM Based TWT Circuit Prototype



# Cold Test Results

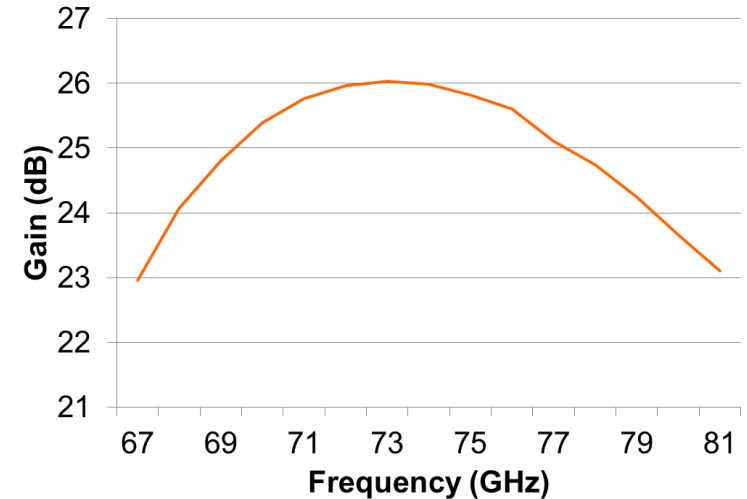
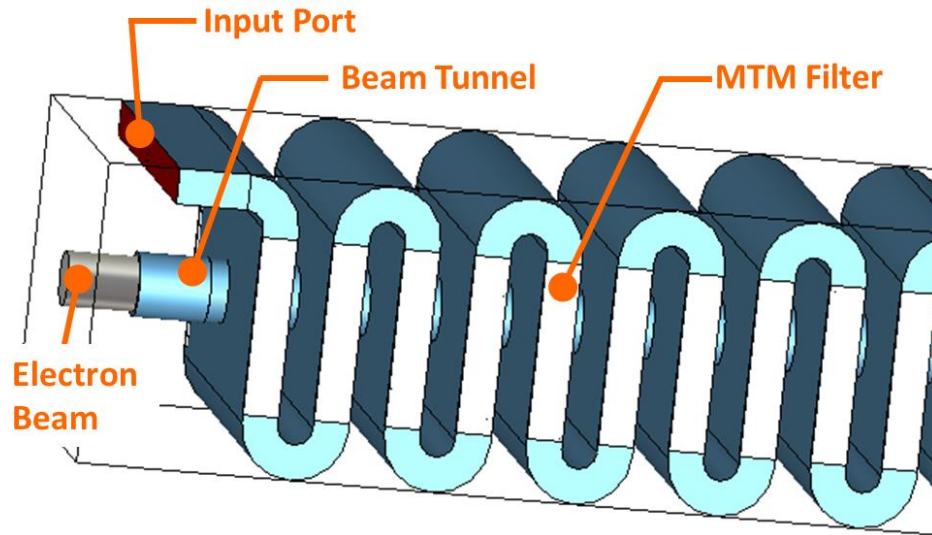


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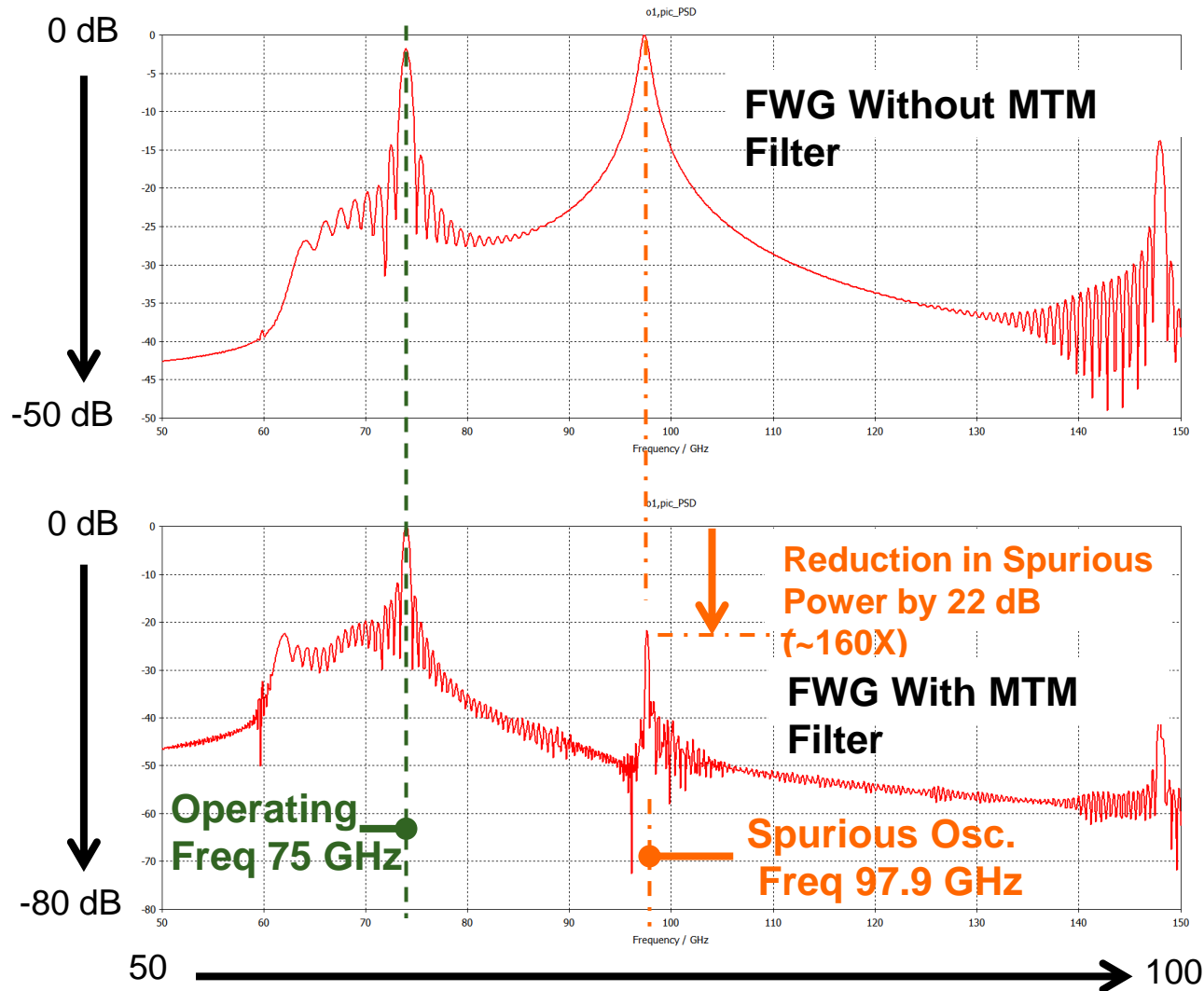
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# 70-80 GHz TWT for Point-to-Point High Speed Links



- **Serpentine waveguide circuit**
- **5 W with 10 GHz bandwidth**
- **Compact and low voltage (<5 kV)**
- **Dual frequency absorbing MTM to suppress band edge oscillations**

# Advantages of a TWT with MTM Filter



# Outline

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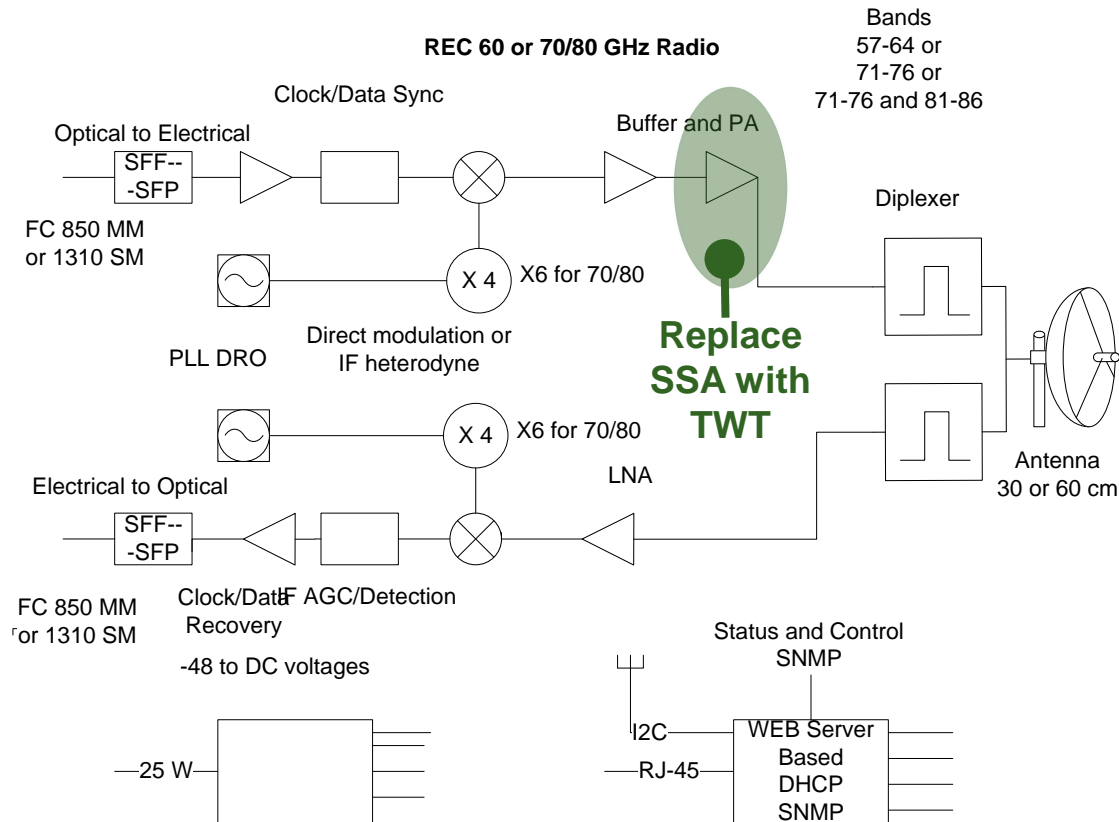
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## Phase II Business Plan

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- **Partnering with Renaissance Electronics Corp, Harvard, MA to jointly develop a high power radio**
  - REC has several radio products in the market
- **Develop a prototype TWT and integrate with REC radio by the end of Phase II**
  - Field demonstration system
  - Supply to early adopters
- **Fully productized system within 2 years of the completion of Phase II**
  - Bridge12's current setup can manufacture 20-30 units/yr

# Integration with REC's E-Band Radio





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# Conclusions

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- **We experimentally demonstrated the advantages of MTM structures in vacuum electron devices during Phase I**
- **In Phase II we will develop a 5W, 70-80 GHz TWT for E-band wireless radios**
  - Partnering with Renaissance Electronics for joint product development
- **Anticipate to have early prototypes in the field by the end of the Phase II program**

# Acknowledgements

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